Influence of Cell Construction on the Electrochemical Reduction of Nitrate

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The electrochemical reduction of nitrates in the weakly alkaline electrolyte, simulating spent solution after regeneration of a strongly basic anion exchanger (concentration of nitrate 1 g dm^{-3}) was studied. Copper was used as the cathode material. This choice was based on the results of the preliminary study (1). The influence of the electrolyser construction, cathode form and process parameters on the current efficiency of the nitrate reduction was followed. Four types of cell construction were compared: a plate electrode cell, a cell with a fluidised bed of inert particles in the interelectrode space, a packed-bed-cathode and a vertically moving particle bed (VMPB) cell.

As expected, highest current efficiency with respect to the nitrate reduction was observed for the VMPB reactor. The final nitrate concentration of 50 mg dm^{-3} was obtained with current efficiency as high as 60 % at the anode (corresponds to the cathode cross-section) current density lower than 20 mA cm^{-2}. On the other hand, relatively low reduction efficiency of approximately 10 % was observed for the packed bed cathode and anode current density up to 40 mA cm^{-2}. Moreover, a serious problem represents high concentration of nitrite in the electrolyte. Unexpectedly high efficiency was observed for the simple plate electrode cell. Nitrate concentration reduction down to 50 mg dm^{-3} wit a current efficiency of approximately 40 % was observed. The disadvantage is very low current density (below 4 mA cm^{-2}) providing such current efficiency. The low current density drawback was minimized applying fluidized bed of inert particles in the interelectrode space. It enhanced limiting mass transfer rate. Fluidized bed enhanced current density providing efficiency higher than 40 % up to 20 mA cm^{-2}. Results obtained for this arrangement are shown in the figure.

The current efficiency of the process was found to dependent strongly on the cell construction. Since we are dealing with diluted solutions, this can be explained by different mass transfer rates in the individual cells. This is especially apparent on the comparison of the plate electrode in an empty channel and in the fluidizing bed of inert particles. This theory was confirmed by the evaluation of the mass transfer coefficients for the individual cell types. Very good agreement with the experimentally observed efficiency of the nitrate reduction was found.

In an apparent disagreement with this theory is the observed low efficiency of the packed bed cathode posing generally high mass transfer rates. This discrepancy follows, however, from the irregular potential distribution in the cell and its geometrical arrangement (flow-by). It enables part of the electrolyte to by-pass electrochemically most active part of the electrode. The irregularity in potential distribution results also in the high nitrite production rate observed for this reactor type.

It is possible to conclude that from the point of view of cell efficiency coupled with simplicity of construction and operation, plate electrode cell with a fludised bed of inert particles in the interelectrode space seems to be an optimal choice for the practical applications. The main product of the nitrate reduction was found to be ammonium. Since we are dealing with the regenerating solution for ion exchanger, it does not contaminate directly drinking water. Nevertheless, further research is necessary to eliminate this undesirable product.

ACKNOWLEDGEMENTS

The financial support of this research by the Grant Agency of the Czech Republic, projects numbers 104/99/0433, and 104/00P016 is gratefully acknowledged.

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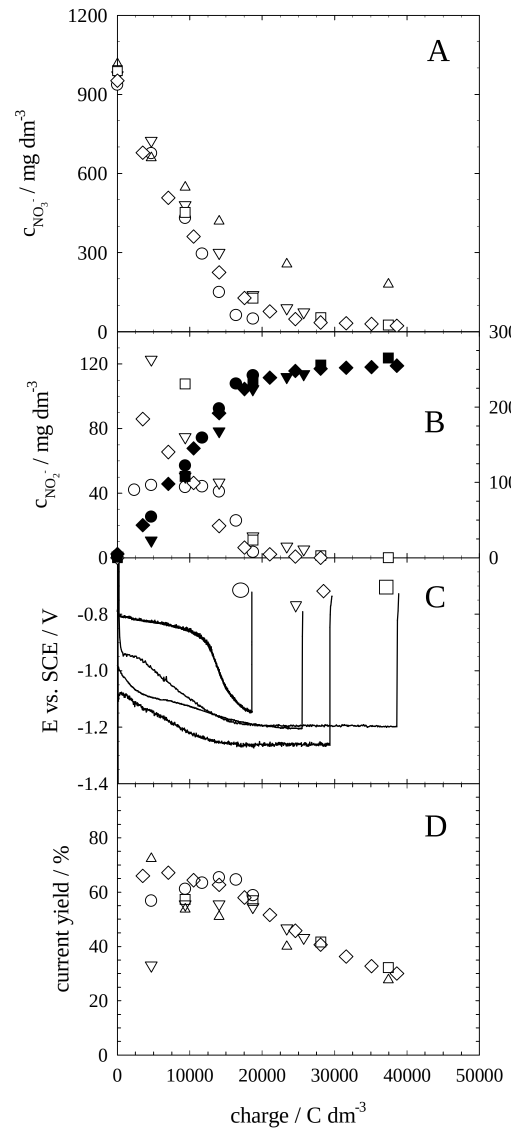

Figure: Electrochemical reduction of nitrate in the cell with the fluidised bed of inert particles in the interelectrode space. Dependence of (A) nitrate concentration, (B) nitrite (empty symbols) and ammonium (filled symbols), (C) cathode potential and (D) current yield with respect to the nitrate reduction on the electrical charge per unit volume of the electrolyte. Cathodic current density: O - 2 mA cm^{-2}, ∇ - 4 mA cm^{-2}, • - 8 mA cm^{-2} and ◊ - 12 mA cm^{-2}; temperature 20 °C.